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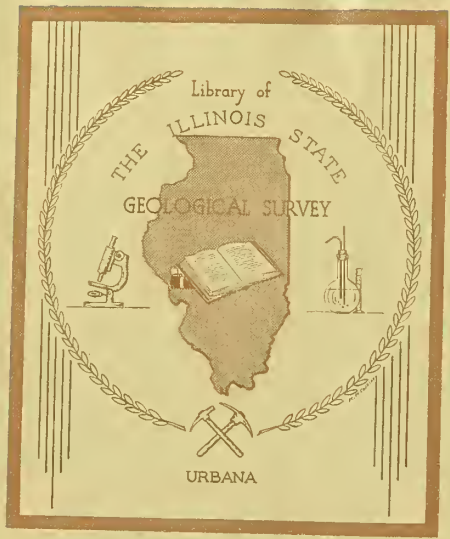
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DISPOSAL OF WASTES:
SCIENTIFIC AND
ADMINISTRATIVE CONSIDERATIONS

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DISPOSAL OF WASTES: SCIENTIFIC AND
ADMINISTRATIVE CONSIDERATIONS*

Robert E. Bergstrom

INTRODUCTION

Waste disposal has long been considered by those concerned with ground water mainly as a factor in ground-water pollution. Today, many ground-water workers are taking a more positive role by studying and classifying hydrogeologic environments relative to waste disposal. This activity is an important aspect of waste management, a term used in an excellent report by the Committee on Pollution of the National Academy of Sciences and the National Research Council (1966) that stresses the constructive aspect of the problem of wastes. The goal of waste management is to protect the sanitary, physical, and aesthetic elements of our environment and to preserve natural resources.

Although waste management includes social, political, economic, scientific, and technological concepts that can be very broad in scope, most of the people at this conference participate in waste management as it is implemented at the state level and as it relates to ground water. Specifically, ground-water practitioners most commonly find themselves cast as experts in the fields of geology and hydrology and as consultants to regulatory agencies, industrial engineers, landfill operators, and John Q. Public. The object of this paper is to review several aspects of waste disposal related to ground water and physical environment, and to suggest some problems to which ground-water practitioners might address themselves.

* Presented at the Midwest Ground-Water Conference, Cincinnati, Ohio, October 26, 1967.

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WASTE DISPOSAL AND CONTAMINATION

Most states, I believe, now have an administrative and statutory structure that, theoretically, is capable of policing waste disposal projects, although such control machinery has not always existed. Today the problem in waste management is halting the ever increasing release of wastes into physical environments that can neither contain them nor assimilate them - and at the same time making sure that waste problems, like wastes, are not simply buried.

In Illinois we have considered the following sources of possible ground-water contamination:

1. Land fills and dumps
2. Radioactive waste burial grounds
3. Sewage treatment and waste storage ponds (including industrial lagoons)
4. Disposal wells
5. Sewage-storm water tunnels
6. Septic systems and privies
7. Livestock feed lots
8. Coal mining and processing operations
9. Oil field operations
10. Agricultural fertilizers and pesticides
11. Highway salting
12. Well construction and abandonment
13. Accidents

The first nine categories involve waste management, but I shall touch mainly on the first five because they include disposal operations in which review by state agencies is customary.

Basically, we are looking for "safe" conditions for disposal, or conditions under which the waste will not release objectionable products into our environment or into useful resources. Conditions may be safe because of climatic, geologic, or hydrologic factors, or combinations of these (Hughes, 1967).

General conditions for the disposal of wastes by shallow burial at land surface are shown in figure 1. The desert landscape in the upper left shows disposal conditions that are safe as a result of a dry environment. Virtually no leaching or downward movement of contaminants takes place because there is little rainfall. The burial medium can be permeable or impermeable.

Conditions depicted at the lower left of figure 1 are safe because of the low permeability of the burial medium. The glacial till allows only slow and local ground-water movement, has a mechanical filtering action, and removes some ions by base exchange.

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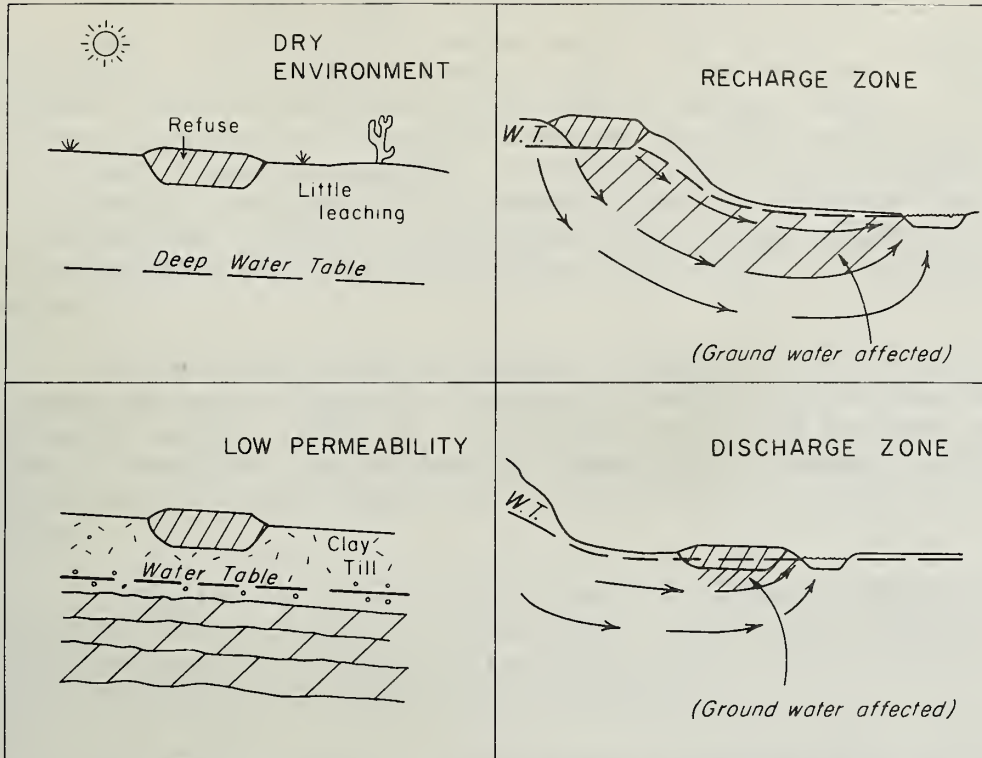


Fig. 1 - Hydrogeologic conditions for disposal of refuse at land surface.

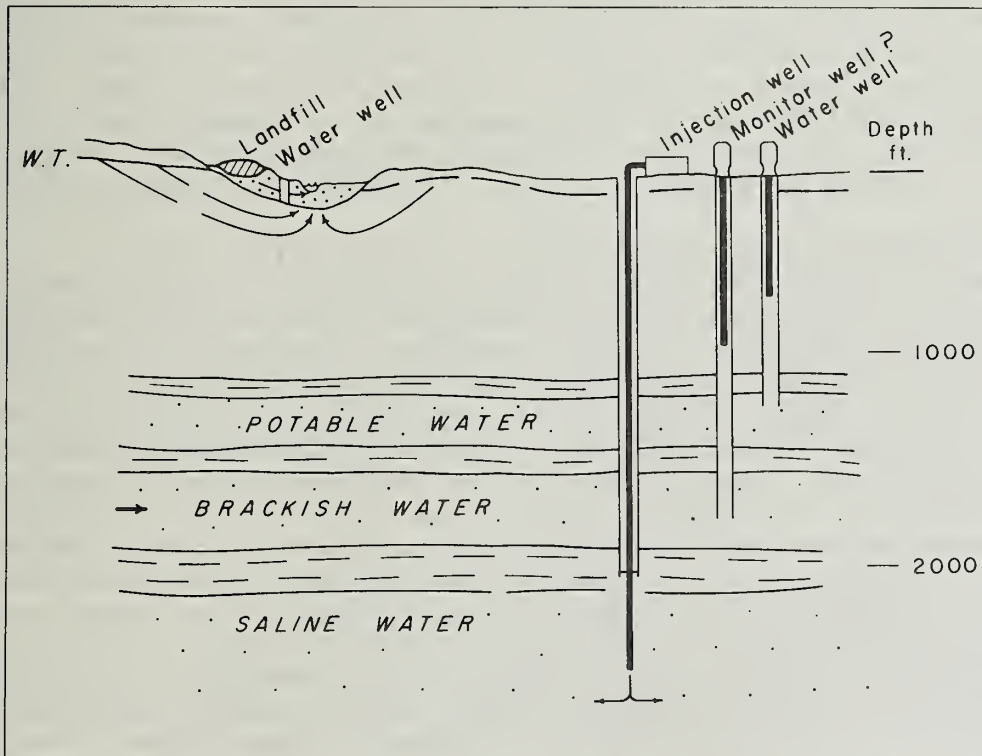


Fig. 2 - Hydrogeologic conditions for disposal of wastes at land surface and by means of deep well injection.

At the upper right of figure 1, disposal of wastes in a recharge zone is shown. The arrows are ground-water flow lines. The refuse might become saturated if burial is taking place in fine-grained, relatively impermeable deposits where the water table is usually high, or it might remain above saturation if burial is taking place in sand and gravel where the water table usually is deeper. If the sediments are permeable, the belt of possible influence of contaminants from the disposal site could be wide, and shallow aquifers could be affected. If the sediments are relatively impermeable, the long flow paths could result in attenuation of contaminants.

At the lower right of figure 1, disposal is at a site in or close to a discharge zone. There is a relatively small, shallow area in which ground water could be affected. The water table would be high, introducing problems of operation and leaching of contaminants. However, discharge would be into the nearby stream; if it were a large stream there would be dilution.

Figure 2 illustrates conditions for surface disposal operations and disposal of liquid wastes in deep wells. There are significant differences in the physical factors involved, the kinds of data sought, and the kind of monitoring system that can be installed.

In surface disposal operations, illustrated (fig. 2) by the land-fill along the side of a valley at the left, the factors controlling feasibility are the topographic relief, position of the water table, amount of precipitation, kinds of earth materials, and location of the disposal zone in the flow system. Usually we are dealing with quite shallow, often complex, dynamic flow conditions, for which we rarely know the hydrologic details. Tight materials generally are sought for surface burial of wastes to reduce the movement of contaminants into the ground-water reservoir. The cost of installing monitoring points may be low, but a fair amount of hydrologic insight is necessary to make the monitoring useful.

In deep well disposal in the Midwest, we are usually dealing with a confined system far removed from topographic and climatic influences, one in which vertical ground-water movement may be negligible. If disposal is in depleted oil reservoirs, unnatural pressure conditions may prevail. Unlike refuse buried at the surface, liquid wastes usually must be treated before injection. In the deep reservoirs shown in figure 2, I have shown the principal ground-water movement as a slight lateral movement. Porous and permeable rocks are sought for deep well disposal, and upper potable waters may be protected by tight caprocks, preferential horizontal flow, controlled injection pressures, and buffer zones of brackish water. Costs for monitoring the lateral movement of injected wastes would be prohibitively high and could not be justified on the basis that the movement would be a public hazard. However, under circumstances in which protection of potable ground water is necessary, monitor wells for giving early warning of pressure and water quality changes might be required between the storage zone and potable water zone, as suggested in figure 2.

EXAMPLES FROM ILLINOIS

Disposal of Radioactive Wastes

The state of Illinois and the U. S. Atomic Energy Commission have recently licensed a private company to operate a burial ground for low-level, solid, radioactive wastes. The wastes are encased in steel drums or concrete containers and buried in trenches 20 to 25 feet deep. The operation is similar to a sanitary landfill, but required considerable preliminary testing and proving. Figure 3 illustrates the conditions at the site. Some 40 or 50 feet of loess and till overlie Pennsylvanian bedrock. The till has some lenses of sand and gravel but over-all permeability is very low. In only one test well in six could any water be pumped (5 gpm). From the pumped well a permeability of 4 gpd/ft² was determined for the more permeable part of the site. Water levels in the test wells ranged from a depth of about 40 feet on the ridge to about 20 feet in the dry valley bottoms. Ground-water discharge appears to be to the strip mine pond about 800 feet from the burial site. A flow velocity of 0.01 ft/day was estimated from the permeability and gradient data.

Investigation for the project brought out several scientific and technological problems of interest to ground-water practitioners, among them:

1. The fine-textured glacial sediments did not lend themselves to the methods of hydrologic testing and analysis that are employed in dealing with aquifers; yet field permeability measurements, with ground-water velocities, were requested by A.E.C. reviewers. The determinations finally made and submitted may be high for the actual burial zone.

2. The details of possible saturation and water movement above the so-called water table are not known. Our experience with piezometers installed in sanitary landfills and various glacial drift terranes in northeastern Illinois (Hughes, 1967) suggests that fine-grained tills are usually saturated closer to the surface than is shown here by water levels in test wells. If this is true for the area tested, it could modify the actual burial conditions from what are shown here. Furthermore, the piezometer response to precipitation at various depths in glacial till suggests that some ground-water movement takes place rather quickly through joints rather than through intergranular openings (Williams and Farvolden, 1967). If this occurs here, it could affect the velocity of ground-water movement and travel time to the pond.

Disposal Wells

Figure 4 illustrates conditions at four disposal well sites in Illinois (Bergstrom, report in press). The two on the left are in the Illinois Basin and the two on the right are in northern Illinois. Lithology is shown on the left of each well, and quality of ground water is shown on the right. The rocks shown as shales are considered good confining beds. Fresh water (less than 1000 ppm total dissolved minerals) and brackish to saline water (more than 5000 ppm) are indicated. The figures to the right of the wells show water quality in ppm dissolved minerals at various depths.

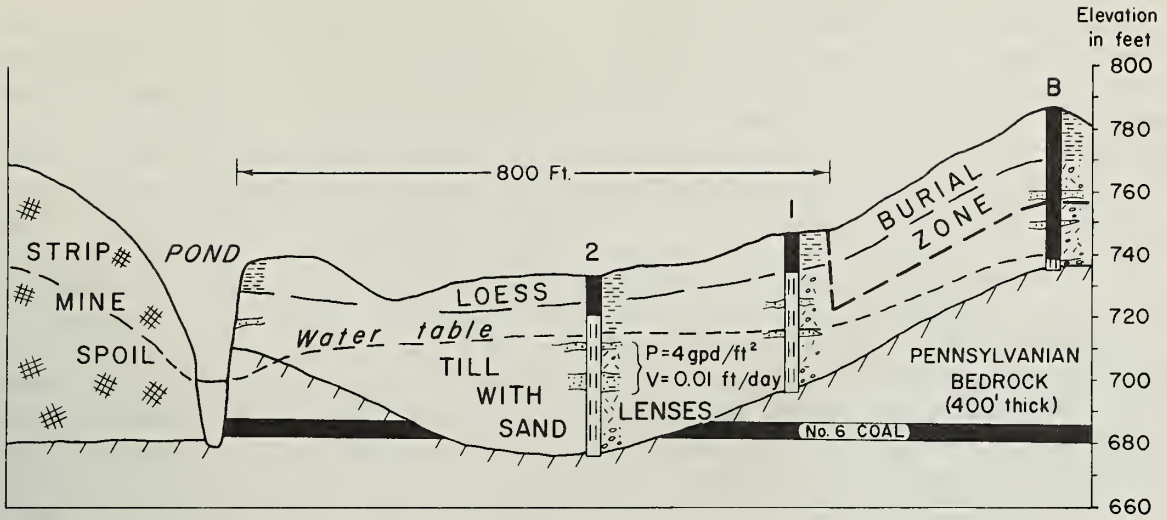


Fig. 3 - Burial ground for low-level, solid, radioactive wastes in Bureau County, Illinois.

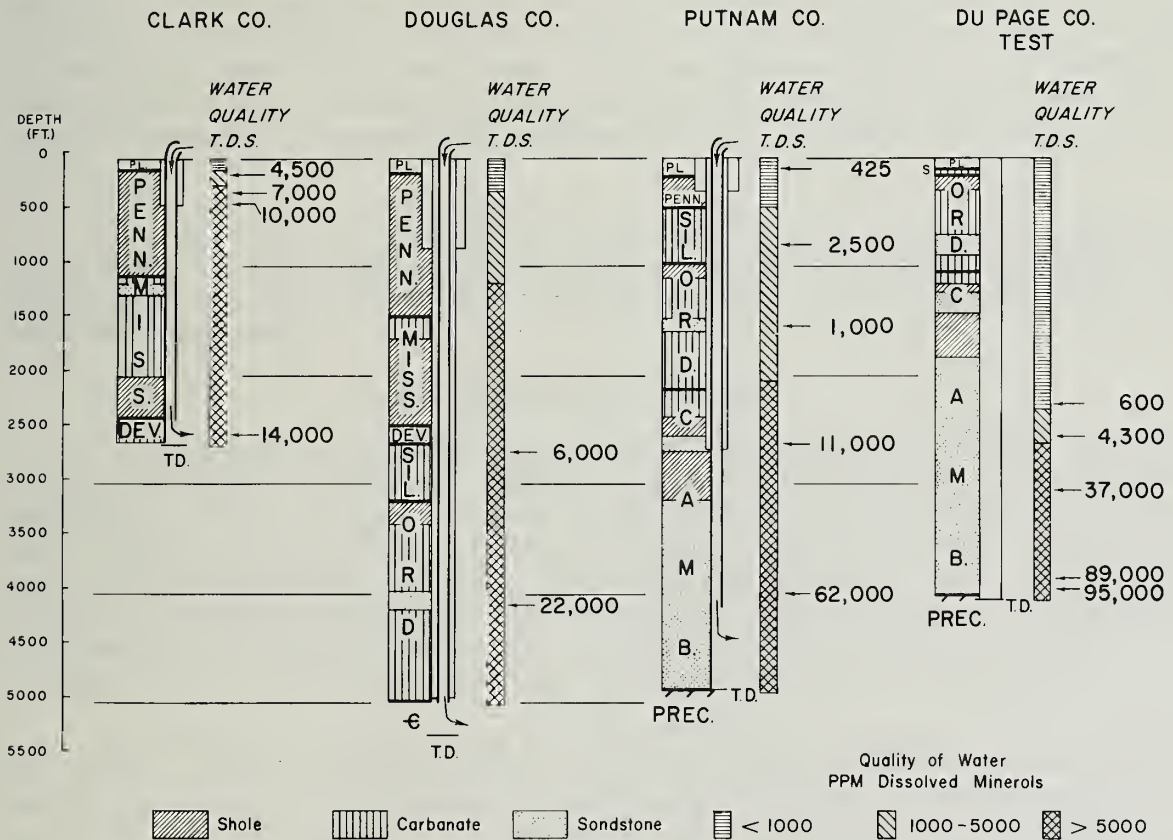


Fig. 4 - Hydrogeologic conditions at waste disposal well sites. Mineral quality of water is given in parts per million total dissolved solids.

At the two sites on the left, fresh water occurs only within a few hundred feet from land surface, and there is considerable shale and brackish to saline water between the disposal zone and upper fresh-water-bearing aquifers. In the Putnam County well, usable water (1000 ppm total dissolved minerals) occurs fairly deep, but there is shale and mineralized water above the disposal zone. In the DuPage County test well at the right, fresh water extends to a depth of about 2300 feet, or into the top 500 feet of a thick sandstone that continues down to the granite basement. The quality of water deteriorates rapidly below 2500 feet; right above granite basement at 4000 feet the water has a dissolved mineral content of 95,000 ppm. The thick sandstone thus contains fresh, brackish, and saline water from top to bottom, with no prominent intervening shale sections, though the sandstone has low permeability. The basal 200 feet of sandstone accepted water at a rate of only 25 gallons per minute at allowable operating pressures. We estimated that nearly 1000 feet of section would be required for injection of waste at 325 gpm. This would bring the injection zone up to about the 3000-foot depth, which we considered too close to the potable water zone.

The main problems were presented by the DuPage County site where there is deep fresh water occurrence and large ground-water development. There is a real need for waste disposal facilities in this part of the state, but it was necessary for state agencies to be very cautious in reviewing the proposal. For example, the State Sanitary Water Board ruled that fracturing of the basal part of the sandstone would not be permitted. Fracturing might have produced the permeability that could have made the project feasible, could it have been accomplished without hazard to potable ground-water supplies.

An additional problem presented by this site was the extent to which water of poor quality might migrate upward as a result of injection of wastes into the lower part of the sandstone and the pumping of potable water from the upper part.

Sewage-Storm Water Tunnels

Another interesting problem in waste management is the Chicago Sanitary District's proposal (Harza Engineering Company and Bauer Engineering, Inc., 1966) to store combined sewage and storm water temporarily in deep tunnels in the Galena-Platteville Dolomite (fig. 5). The water would enter the tunnels during storms, and after storms would be processed in the Sanitary District's treatment plants and then returned to the Sanitary Canal. At present, during many storms the treatment plants are by-passed and the combined storm water and raw sewage are fed directly into the canal.

A final investigation of feasibility and design has been started. The initial report concluded that storm and sewage water would not pollute the ground-water reservoir because the rock in which the tunnel would be excavated is quite tight, and head relations are such that any water movement would be into rather than out of the tunnel. The present head is well above the proposed tunnel section. However, by the year 2010, pumpage might have drawn the head down below the tunnel level. To prevent this from occurring, artificial recharge into the St. Peter Sandstone in the tunnel area and distribution of water and head in the Galena-Platteville would keep the head above the tunnel and assure head relations that would keep pollution from entering the dolomite.

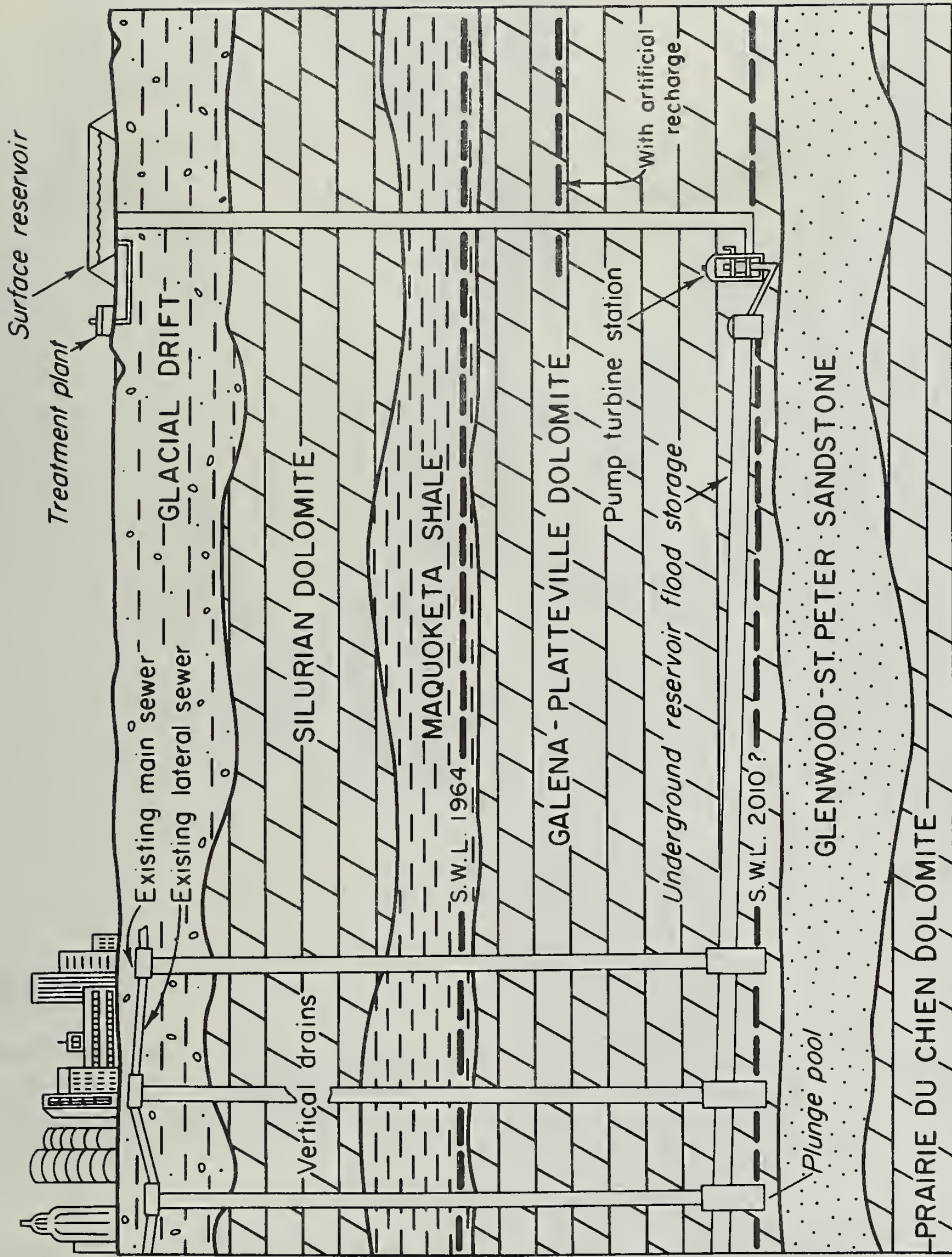


Fig. 5 - Schematic plan for combined sewage-storm water storage tunnel for Chicago.

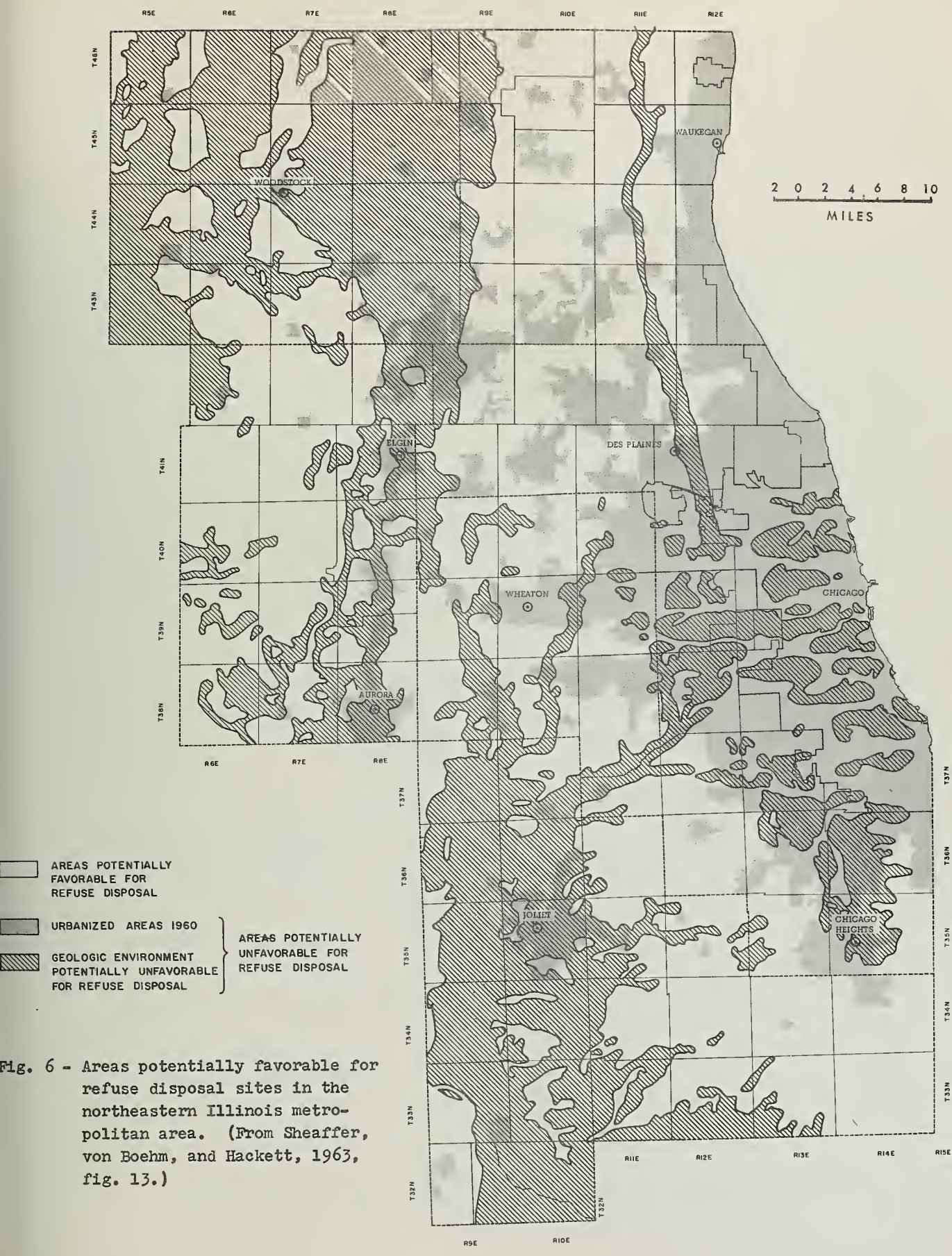


Fig. 6 - Areas potentially favorable for refuse disposal sites in the northeastern Illinois metropolitan area. (From Sheaffer, von Boehm, and Hackett, 1963, fig. 13.)

SOUTHERN LIMITS OF
USE OF DEEP SANDSTONES
AS POTABLE WATER SOURCES

MT. SIMON

GALESVILLE
ST. PETER

QUESTIONABLE

SOMEWHAT FAVORABLE

IN DEEP (CAMBRIAN)

ROCKS

SOMEWHAT

FAVORABLE;

FAVORABLE;

MANY RESERVOIRS,
VARIOUS DEPTHS

VARIOUS DEPTHS

⊕ Somewhat favorable in
Cambrian rocks

• Waste disposal well

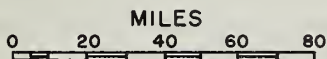


Fig. 7 - Subsurface waste disposal possibilities in Illinois.

Among the problems posed by this project, and these were mentioned by Hackett (1967) at the National Water Well Association meeting in Des Moines, are possible regional hydrologic effects produced by the elimination of immediate storm water runoff in the Chicago area, and the transfer of a possible pollution source into a major aquifer, with artificial recharge required to keep the system functioning properly.

CONCLUSIONS

I should like to conclude by mentioning some of the things I believe ground-water practitioners could be doing in waste management.

First, in addition to maintaining a vigilance over pollution hazards connected with waste disposal, we should exercise our knowledge of hydrogeologic conditions to promote sites and environments for waste disposal where there are natural safeguards that will assure protection of health and resources. We should also point out environments where risks of pollution hazard are high. Even the use of fairly broad hydrogeologic generalizations with reference to disposal conditions are useful to the regulatory and planning agencies and to the interested public, and they can keep ill-advised projects from being developed. For example, figure 6 categorizes conditions for solid waste disposal in northeastern Illinois (Sheaffer, von Boehm, and Hackett, 1963). The unfavorable areas are underlain by sand and gravel or limestone aquifers with little or no drift cover.

Figure 7 shows the hydrogeologic feasibility of deep waste disposal wells in Illinois (Bergstrom, report in press). Conditions range from very good in the Illinois Basin, where there is a thick geologic section and highly mineralized water below shallow depth, to highly questionable in the northern part of the state, where there is a thinner section and deep fresh water penetration.

Second, in reviewing proposals for specific waste disposal sites in cooperation with other specialists, we are in a position to stimulate the acquisition of useful data on the physical system and to promote the development of criteria for assessing the protection afforded by certain geologic conditions and engineering practices. Decisions should be based on facts rather than on the absence of facts.

Finally, we should delve into investigations that are especially pertinent to waste management problems. There should be studies of saturation conditions and water movement in typical geologic materials and terranes that might be used for disposal of wastes. Methods of investigation and hydrologic analysis should be developed for environments having fine-textured, relatively impermeable sediments. Geochemical factors that may affect attenuation of contaminants should be further considered. And studies should be made of the means by which injected liquid wastes are accommodated in subsurface reservoirs and of the possible role of hydrofracturing in facilitating waste injection into deep, impermeable rocks.

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